

DESIGN SEMI-ACTIVE SUSPENSION USING MAGNETO –RHEOLOGICAL DAMPER

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A report submitted in partial fulfilment of the requirements
for the award of the degree of
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I certify that the project entitled “*Design Semi-Active Suspension Using Magneto-Rheological Damper*” is written by *Muhamad AmzanSani Bin Abd Wahab*. I have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. I herewith recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering with Automotive Engineering.

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for the quotations and summaries which have been duly acknowledged. The project has not been accept for any degree and is not concurrently submitted for any award of other degree.

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ABSTRACT

This thesis focused on the development of semi- active suspension by using magneto-rheological damper. The MR damper is a type of damper that used MR fluid as working fluid which enables us to change damping force and setting of suspension without need to setting manually damper itself. It can be achieve by changing the current flow on it magnetic circuit. This thesis first introduces MR technology through a discussion of MR fluid and then by giving a broad overview of MR devices that is being developed. After giving the reader an understanding of MR technology and devices, MR damper basics are presented. This section includes a discussion of MR damper types, mathematical fundamentals, and an approach to magnetic circuit design. With the necessary background information covered, MR dampers for automotive use are then discussed. Then come to design part. By using specification same as Proton Waja passive damper, the model was develop by using SOLIDWORK software. The design used twin tube damper with same size of outer tube of OEM damper. The parameter like number of turn, length and diameter of the wire, current induced, magnetic field generated, head piston velocity, and force produced by MR damper was be calculated and discussed. The result show the damper produced 6475.441 Newton of maximum force when 3 ampere of current being applied to the damper. The force generated by damper at 0.5, 1, 1.5, 2, 2.5 and 3 ampere was plotted in a single graph versus piston head velocity in order to give better view of result.

ABSTRAK

Tesis ini memfokuskan pada pembangunan suspensi semi- aktif dengan menggunakan cecair magnetik yang dikenali sebagai cecair MR. Perendam MR adalah sejenis perendam yang menggunakan cecair MR sebagai medium operasinya dimana membenarkan kita mengubah daya perendaman dan ketetapan sesebuah suspensi dengan mudah. Ini dapat dicapai dengan mengubah arus elektrik yang mengalir pada litar magnetik yang terdapat dalam perendam. Dalam tesis ini, pertamanya diterangkan mengenai teknologi MR melalui penerangan tentang cecair MR dan secara am tentang alat MR yang sedang di bangunkan. Kemudian penerangan tentang perendam MR akan di terangkan. Dalam bahagian ini semua perbincangan tentang jenis perendam MR, teori matematik, dan pengenalan pada rekaan litar magnetik. Dengan maklumat asas telah diterangkan, perendam MR untuk automotif dibincangkan. Kemudian kepada bahagian rekaan. Rekaan akan berdasarkan kepada perendam pasif Proton Waja. Dengan menggunakan spesifikasi sama seperti perendam Proton Waja, model perendam dibina dengan menggunakan perisian SOLIDWORK. Rekaan menggunakan tiub berkembar yang sama saiz dengan tiub luar perendam OEM. Semua parameter termasuk bilangan lilitan wayar, panjang dan diameter wayar yang digunakan, arus elektrik yang dikenakan, kekuatan medan magnet yang terjana, halaju piston perendam, dan daya yang terhasil akan dikira dan dibincangkan. Keputusan menunjukan yang perendam menghasilkan daya maksimum sebanyak 6475.441 Newton apabila dikenakan arus 3 ampere. Daya yang terhasil oleh perendam pada arus 0.5, 1, 1.5, 2, 2.5 dan 3 ampere di plotkan dalam satu graf bagi membolehkan keputusan dilihat dengan lebih baik.

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LIST OF SYMBOLS

α	Fluid efficiency
τ_y	Yield stress
η	Plastic viscosity
μ	Relative permeability of the material
μ_0	Free space permeability ($4\pi \times 10^{-7}$ Tm/A)
Φ	Magnetic flux

LIST OF ABBREVIATIONS

FYP	Final Year Project
MR	Magnetic-Rheological
OEM	Original Equipment Manufacturer
PTFE	Polyethylene

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Over the past decade, there has been a sustained interesting magneto rheological (MR) device due to the controllable interface provided by the MR fluid inside the devices that enables the mechanical device to interact with an electronic system, which can be used to continuously adjust the mechanical properties of the device. Some examples of devices in which MR fluids have been employed include dampers, clutches, brakes and transmissions. The most popular of these devices are MR dampers, especially as automotive shock absorbers. The automotive shock absorber has been shown to be a very important contributor to the ride comfort and road handling of a vehicle. For ride comfort, shock absorbers with a ‘soft’ setting are required to dissipate shock energy from the road, while a ‘hard’ setting is required for good vehicle handling. These conflicting characteristics of ride comfort and road-holding is a major challenge to automotive shock absorber designers. The tuning of conventional hydraulic shock absorbers normally involves the physical adjustments of the settings of various valves located inside the piston. Also, conventional absorbers will have a constant setting throughout their lifetime, and hence will not be able to operate satisfactorily in a wide range of road conditions. It is for these reasons that semi-active systems like MR dampers have attracted the attention of suspension designers and researchers. MR dampers are not only advantageous in their ability to provide variable damping forces to the suspension; they are inherently fail-safe devices from an electronic point of view. If there was a fault in the system, the MR damper can still operate as a passive damping system

within certain performance parameters depending on the off-state characteristics of the MR fluid inside.

1.2 PROBLEM STATEMENT

Traditionally, automotive suspension designs have been a compromise between the two conflicting criteria of road holding and passenger comfort. The suspension system must support the weight of the vehicle, provide directional control during handling maneuvers, and provide effective isolation of passengers and payload from road disturbances. A passive suspension has the ability to store energy via a spring and to dissipate it via a damper. The parameters are generally fixed, being chosen to achieve a certain level of compromise between road holding and ride comfort. Once the spring has been selected based on the load-carrying capability of the suspension, the damper is the only variable remaining to specify. Low damping yields poor resonance control at the natural frequencies of the body (sprung mass) and axle (unsprung mass), but provides the necessary high frequency isolation required for a comfortable ride. Conversely, large damping results in good resonance control at the expense of high frequency isolation. Due to these conflicting demands, suspension design has had to be something of a compromise, largely determined by the type of use for which the vehicle is designed. The other solution is using active control. However this method is expensive for a standard car.

1.3 OBJECTIVES

The primary objectives of this thesis is

- i) To design MR damper geometry
- ii) To develop MR damper about MR damper geometry and magnetic field
 - o To determine the magnetic induction
 - o To determine the magnetic field intensity
- iii) To analyze the MR parameter.

1.4 Scope

The scope for this thesis is

- i) Design a MR damper by using the same dimension of outer tube of Proton Waja
- ii) To determine the diameter of wire that will use for the coil inside the MR damper
- iii) To calculate the strength of magnetic induction and its field intensity
- iv) To determine maximum force that MR damper can absorb

CHAPTER 2

LITERATURE REVIEW

2.1 BACKGROUND

The purpose of this chapter is to orient the reader with the topic of magneto rheological fluid technology. From this point forward, magneto rheological fluid will be referred to simply as MR fluid. MR fluid belongs to a class of materials that are known as "smart materials". The physical attributes of smart materials can be altered through the application of an electrical, magnetic, or thermal stimulus. Some smart materials, known as Piezoceramics, exhibit a change in physical size when an electric current is passed through them. Other materials, known as Shape Memory Alloys, can be deformed and then returned to their original dimensions through the application of heat. Still other materials, known as ER (electro rheological) fluids and MR fluids, exhibit a change in apparent viscosity when activated.

2.2 TYPES OF SUSPENSION

Suspension is the term given to the system of springs, shock absorbers and linkages that connects a vehicle to its wheels. Suspension systems serve a dual purpose – contributing to the car's road holding/handling and braking for good active safety and driving pleasure, and keeping vehicle occupants comfortable and reasonably well isolated from road noise, bumps, and vibrations. These goals are generally at odds, so the tuning of suspensions involves finding the right compromise. It is important for the suspension to keep the road wheel in contact with the road surface as much as possible, because all the forces acting on the vehicle do so through the contact patches of the

tires. The suspension also protects the vehicle itself and any cargo or luggage from damage and wear. The design of front and rear suspension of a car may be different. Generally there are three type of suspension. There passive, semi active, and last one active.

2.2.1 PASSIVE SUSPENSION

The typical passive suspension system can be considered as a spring in parallel with a damper placed at each corner of the vehicle like Figure 2.1. The spring is chosen based solely on the weight of the vehicle, while the damper is the component that defines the suspensions placement on the compromise curve. Depending on the realistic condition of vehicle, a damper is chosen to make the vehicle perform best in its application. Ideally, the damper should isolate passengers from low-frequency road disturbances and absorb high-frequency road disturbances. Passengers are best isolated from low-frequency disturbances when the damping is high. However, high damping provides poor high frequency absorption. Conversely, when the damping is low, the damper offers sufficient high-frequency absorption, at the expense of low-frequency isolation.

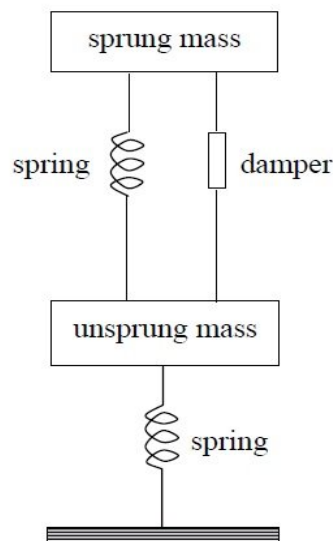


Figure 2.1 Passive suspension

2.2.2 SEMI – ACTIVE SUSPENSION

If the suspension is externally controlled then it is a semi-active or active suspension - the suspension is reacting to what are in effect "brain" signals like Figure 2.2. As electronics have become more sophisticated, the opportunities in this area have expanded. For example, a hydro pneumatic Citroën will "know" how far off the ground the car is supposed to be and constantly reset to achieve that level, regardless of load. It will not instantly compensate for body roll due to cornering however. Citroën's system adds about 1% to the cost of the car versus passive steel springs. Semi-active suspensions include devices such as air springs and switchable shock absorbers, various self-leveling solutions, as well as systems like Hydro pneumatic, Hydrolastic, and Hydragas suspensions. Mitsubishi developed the world's first production semi-active electronically controlled suspension system in passenger cars; the system was first incorporated in the 1987 Galant model. Delphi currently sells shock absorbers filled with a magneto-rheological fluid, whose viscosity can be changed electromagnetically, thereby giving variable control without switching valves, which is faster and thus more effective. The regulating of the damping force can be achieved by adjusting the orifice area in the damper, thus changing the resistance of fluid flow. Most recently the possible application of electrorheological and magnetorehological fluids to the development of controllable dampers has also attracted considerable interest

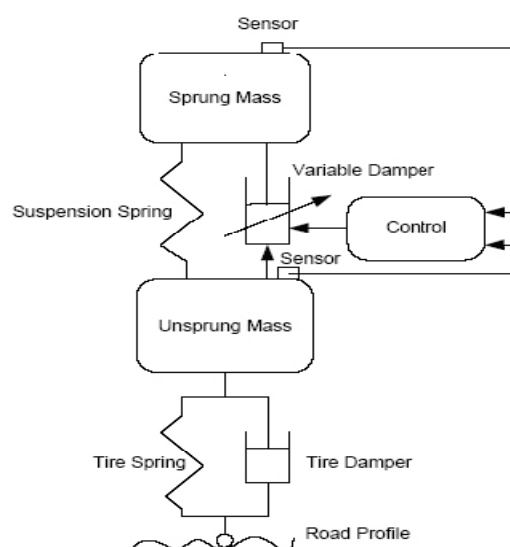


Figure 2.2 Semi-Active suspension

2.2.3 ACTIVE SUSPENSION

Active or adaptive suspension is an automotive technology that controls the vertical movement of the wheels via an onboard system rather than the movement being determined entirely by the surface on which the car is driving. The system therefore virtually eliminates body roll and pitch variation in many driving situations including cornering, accelerating, and braking. This technology allows car manufacturers to achieve a higher degree of both ride quality and car handling by keeping the tires perpendicular to the road in corners, allowing for much higher levels of grip and control.

An onboard computer detects body movement from sensors located throughout the vehicle and, using data calculated by opportune control techniques, controls the action of the suspension. Active suspensions, the first to be introduced, use separate actuators which can exert an independent force on the suspension which show in Figure 2.3 to improve the riding characteristics. The drawbacks of this design (at least today) are high cost, added complication/mass of the apparatus needed for its operation, and the need for rather frequent maintenance and repairs on some implementations. Maintenance can also be problematic, since only a factory-authorized dealer will have the tools and mechanics who know how to work on the system and, some issues can be difficult to diagnose reliably. It also require a huge power supply

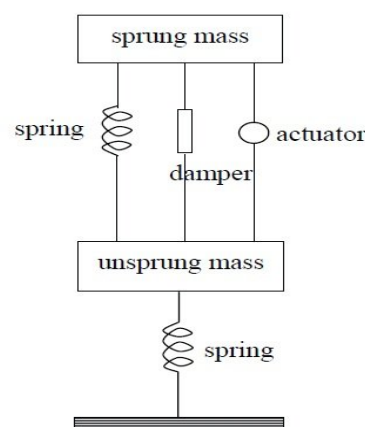


Figure 2.3 Model Active suspensions

2.3 MR FLUID PERFORMANCE

The capability of MR fluid lies in its ability to change the apparent viscosity proportional to an applied magnetic field due to the polarization of ferrous magnetic particles as seen in Figure 2.4. This apparent viscosity change is actually due to altering the yield stress of the MR fluid.. ER fluids are activated by exposure to an electric charge and MR fluids are activated by exposure to a magnetic field. When a magnetic field passes through MR fluid, it develops a yield stress which must be achieved before the material will flow. The piston is wrapped in magnet wire and generates magnetic flux in the piston, cylinder, and MR fluid. When subjected to intense magnetic fields (1 T), the yield stress of the MR material increases from less than 0.1 kPa to roughly 100 kPa. This change in material properties is sufficient to increase damping forces by a factor of 10 or more.

The iron particles are usually in a carrier fluid such as hydrocarbon oil, water, or silicone. The ferrous particles of iron may be from 1-20 microns in size .Many variations of the quantity of ferrous iron to fluid ratios exist for MR fluid. To retain a flowing fluid, the percentage of ferrous particles is typically limited to 20-40% in the composition of the MR fluid. Through magnetic activation at varied magnetic field intensities, MR fluid changes its apparent viscosity which is related to the content of ferrous particles. Therefore, this rheology behavior has enabled many passive devices to be operated with multifunctional capability to provide semi-active control. MR fluid has a very fast response time of less than 10 ms, when a magnetic field is applied. This extremely fast and adaptive behavior allows MR fluid to be controlled with an applied magnetic field. Moreover, the fast and reversible rheology helped MR fluid progress into automotive applications like the shock absorber. Since shock absorbers (dampers) dissipate energy based on the viscosity of the damper fluid, the viscosity is selected to offer either a comfortable ride or a responsive handling ride in the primary suspension of a vehicle. Moreover, with MR fluid in a damper, both of these ride characteristics can be achieved.

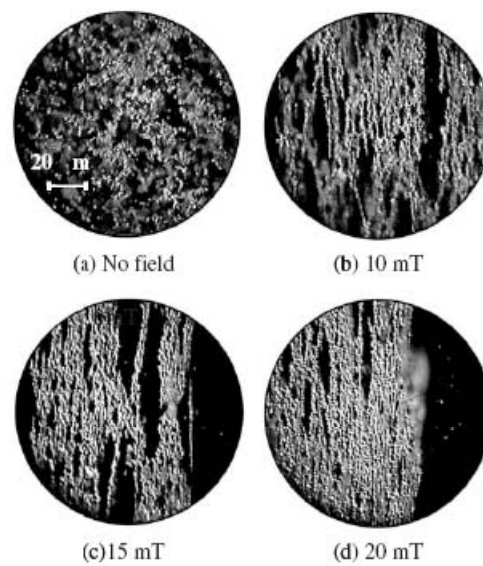


Figure 2.4 Polarization of ferrous magnetic particles

With the aforementioned magnetic particles suspended in a carrier fluid, several modes of operation can occur. Therefore, this section presents the operational modes of MR fluid. The primary mode of fluid operation for a damper is valve mode. Valve mode uses the flow of the fluid passing between magnetic poles, as seen in Figure 2.5, which is also referred to as pressure driven flow mode as described by Lord Materials Division. During valve mode, the applied magnetic field is varied across the fluid gap to cause an apparent viscosity change in the fluid. If used in a damper, the applied magnetic field through the fluid can alter the energy dissipated by the damper. Therefore, the damper may offer a soft ride or a stiff ride.

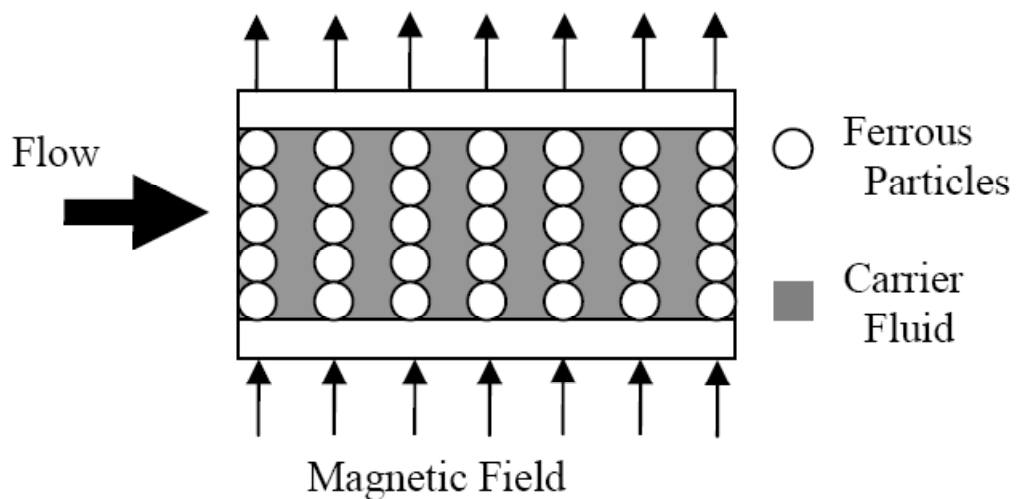


Figure 2.5 Valve mode model

Due to the ease of construction and the effectiveness of their magnetic configurations, most MR dampers are designed as fixed-pole valve mode devices, where the MR fluid is forced to flow through magnetically active annular gaps. In fixed-pole valve mode devices, the positions of both magnetic poles are stationary relative to one another during their operation, with the flow of the fluid generating the damping force provided by the device. This damping force can therefore be continuously regulated by controlling the strength of the applied magnetic field. Because the magnetically active gap is usually very small relative to the radius of the annulus, researchers have exploited this feature to approximate the flow of MR fluid through the annulus with fluid dynamics equations for flow through two infinitely wide parallel plates, a concept first introduced by Phillips for ER fluids and has been utilised widely in the design and modelling of MR dampers

The damper has a double-tube configuration consisting of two concentric cylinders. The piston, which is fixed onto the piston rod, moves up (rebound) and down (compression) along the inside of the inner tube. The piston divides the damper into two parts, namely: the rebound chamber, which is the space above the piston, and the compression chamber, which is the space below the piston. Holes at the bottom of the inner tube allow the compression chamber to be a continuous part of the outer tube. The gas phase on the outer cylinder is filled with pressurised air. Unlike single-tube